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(54) **Method of evaporating and condensing a volatile component, particularly for recovery of solvent in printing processes, and apparatus for carrying out the method**

(57) A method and apparatus for evaporating and condensing a volatile component is provided, particularly suitable for recovering printing ink solvent. The volatile component is evaporated by waste heat from a refrigerator unit condenser applied directly to the component or applied to heat a gas, such as air, to be passed over or through the component. The solvent vapour is condensed by a refrigerator unit evaporator and the heat extracted from the vapour, recirculated in the refrigerant medium to the condenser. In an embodiment using air to dry a printed paper web, the air is heated in refrigerator unit condenser 8' and then passed into chamber 25 through which the web 24 is passed. The resultant solvent vapour/air mixture is passed to refrigerator unit evaporator 10 where the solvent vapour is condensed and then the air is returned to condenser 8.

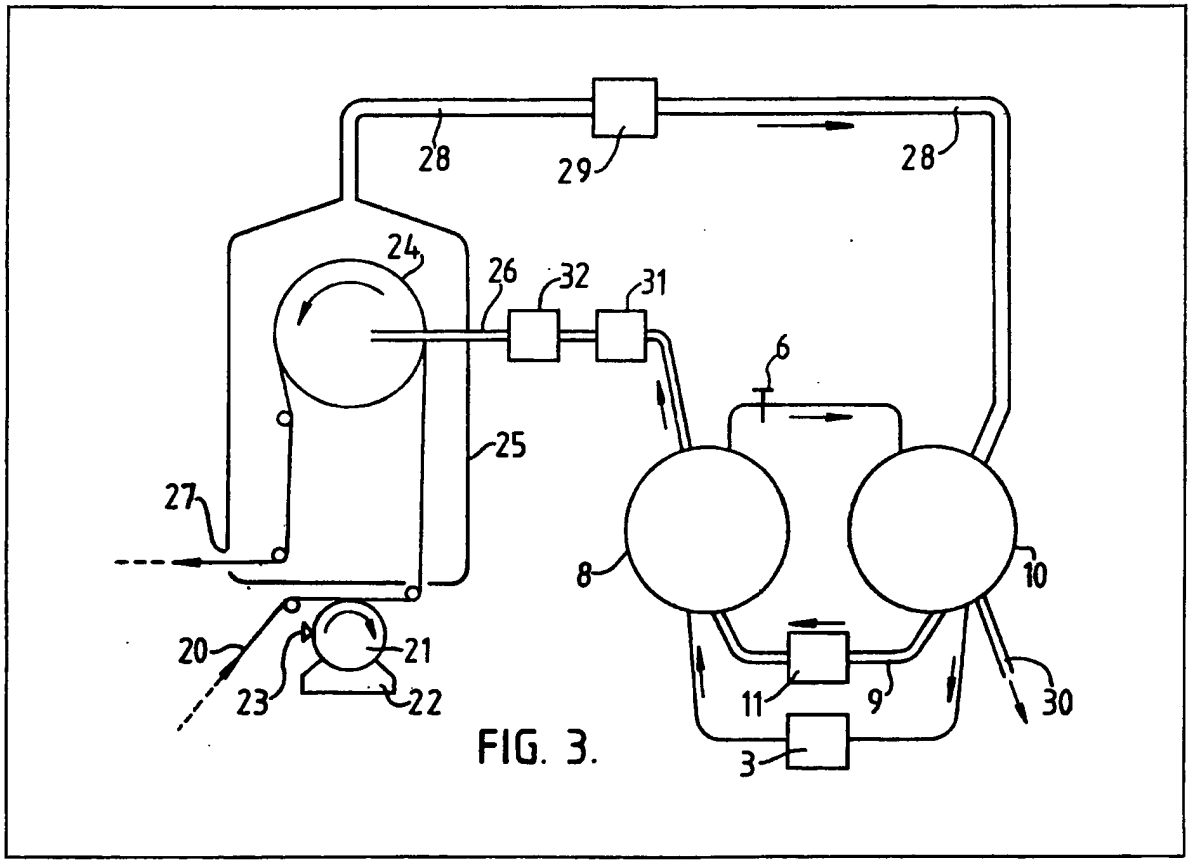

FIG. 3.

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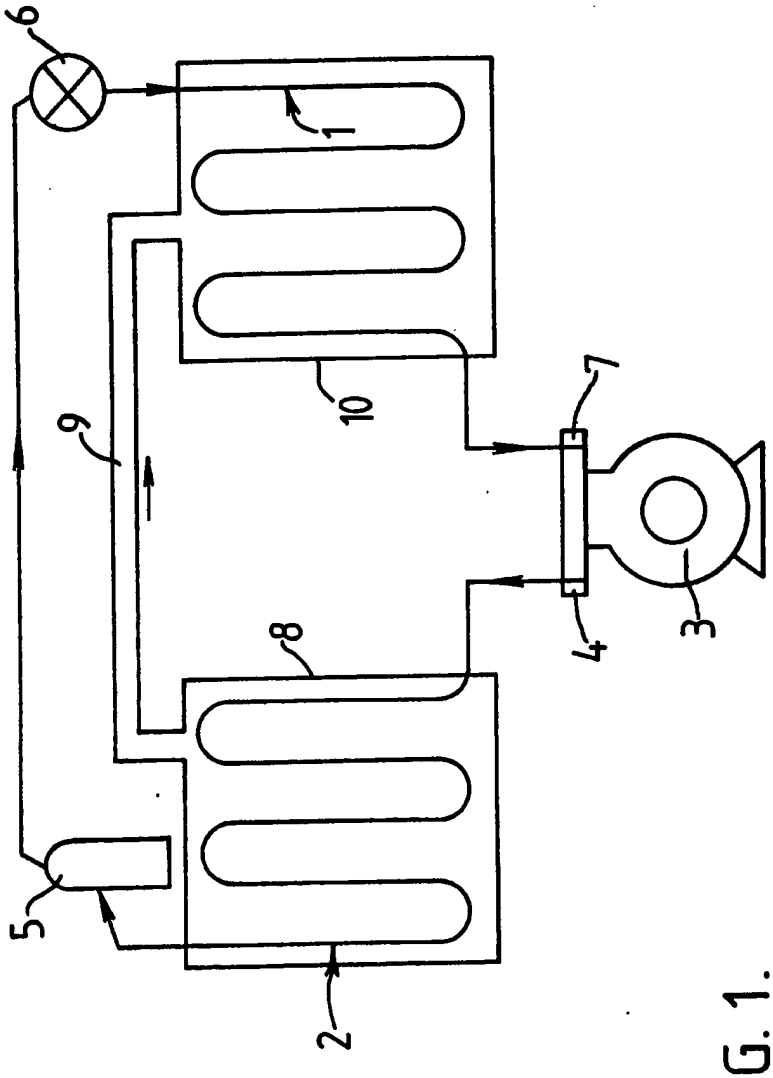

FIG. 1.

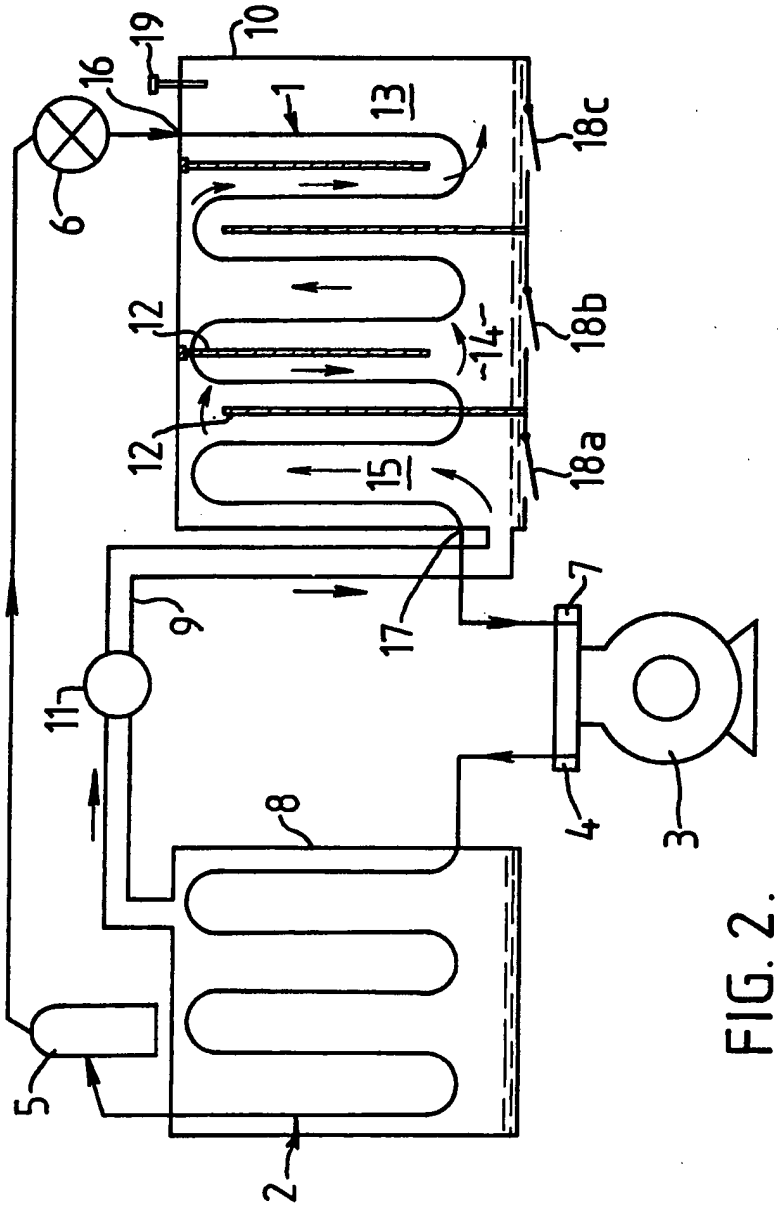

FIG. 2.

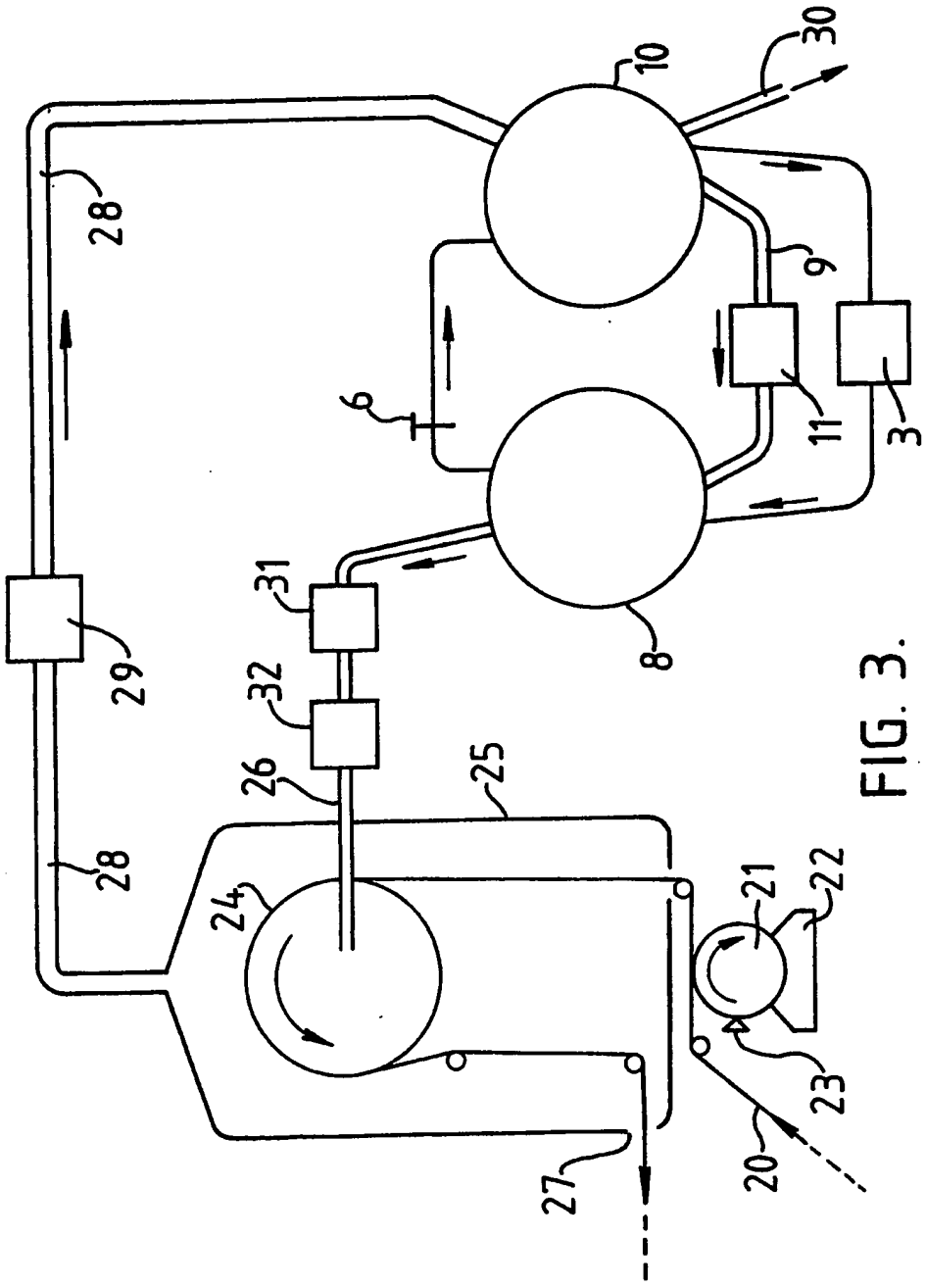

FIG. 3.

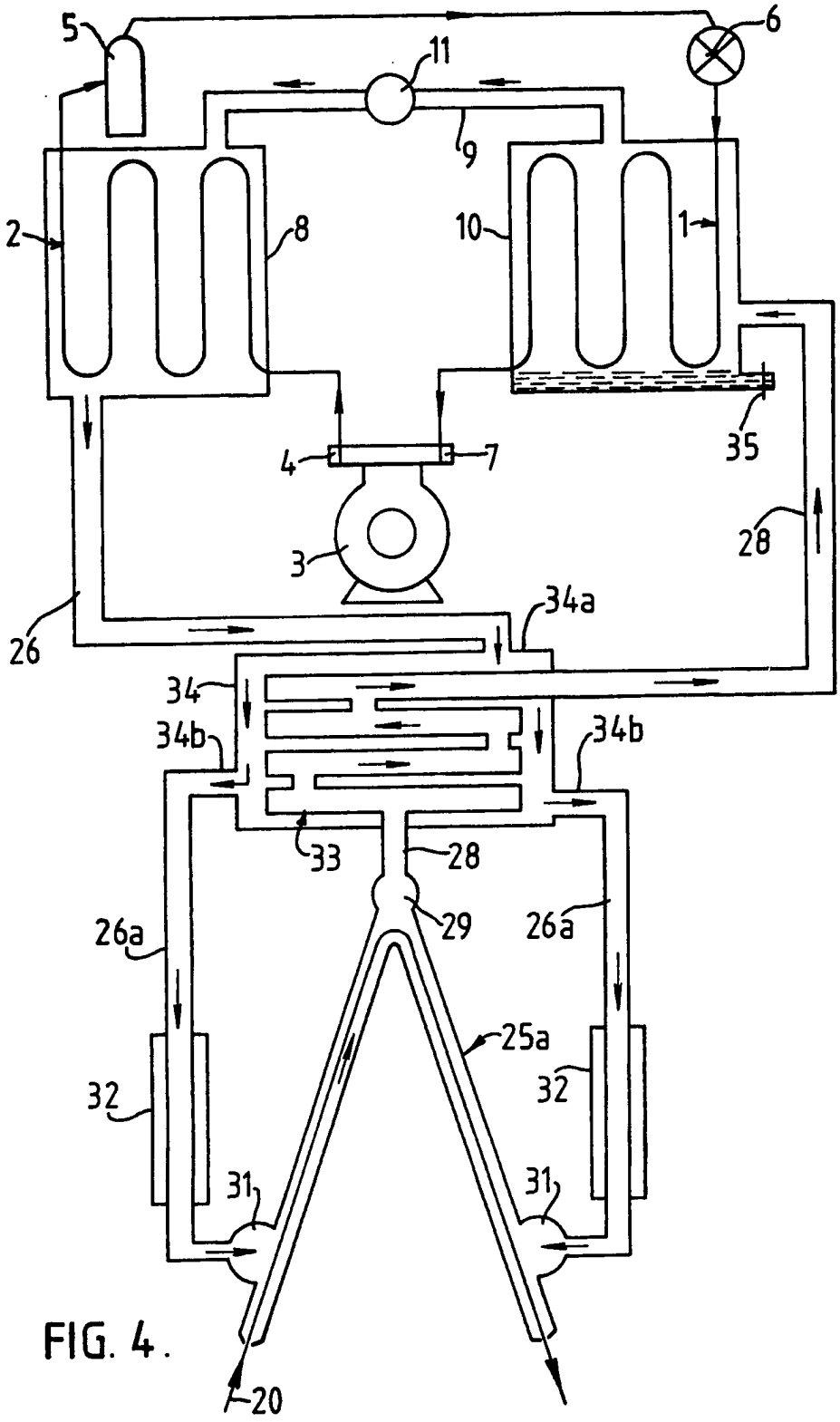
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FIG. 4.

SPECIFICATION

Method of vaporating and condensing a volatile component, particularly for recovery of solvent in printing processes, and apparatus for carrying out the method

This invention relates to a method of evaporating and condensing a volatile component, particularly, but not exclusively, for recovery of solvent and heat in printing and other processes involving drying and/or distillation, and apparatus for carrying out the method.

According to one aspect of the present invention there is provided a method of evaporating and condensing a volatile component, in which a volatile component is evaporated to a vapour from a solid, a solution or a liquid mixture by waste heat of a condenser of a refrigerator unit applied directly to heat the solid, solution or liquid mixture and/or applied to heat a gas to be passed over or through the solid, solution or liquid mixture, and in which at least a substantial proportion of the evaporated volatile component vapour is then condensed to a liquid by an evaporator of the refrigerator unit.

According to another aspect of the present invention there is provided apparatus for carrying out the immediately foregoing method including a refrigerator unit having an evaporator, a condenser and means for circulating a heat exchanging refrigerant medium through the evaporator and condenser, a first sealable container for receiving the solid, solution or liquid mixture from which a volatile component is to be evaporated or for receiving a gas to be passed over or through the solid, solution or liquid mixture, which first container houses the condenser, and a second sealable container, in communication *via* a connecting conduit, with the first container, for receiving volatile component vapour to be condensed and housing the evaporator.

Preferably in the method of the invention the solid, solution or liquid mxiture or the gas to be passed over or through the solid, solution or liquid mixture is received in a first sealable container housing the condenser, which first container is in communication with a second sealable container, housing the evaporator, *via* a flameproof centrifugal pump or motor, and the pressure in the first container is decreased and the pressure in the second container is increased above atmospheric pressure by the pump or motor to lower the boiling point of the volatile component in the first container and to raise the liquifying point of the volatile component vapour in the second container.

Such a method is provided, according to a further aspect of the invention, as applied to a printing press for recovering printing ink solvent, in which heated air is passed over a freshly printed web of sheet material to vapourise volatile printing ink solvent and entrain it therein, the air and entrained solvent vapour are passed to the second container wherein a substantial proportion of the solvent vapour is condensed to liquid solvent by the refrigerator unit evaporator and removed therefrom, and the partially cooled air and remaining entrained solvent is passed from the second container to the first container where it is heated by the refrigerator unit condenser, and returned to the printed web of sheet material for further solvent evaporation.

Apparatus for carrying out the immediately foregoing method is provided according to yet another aspect of the present invention, including a refrigerator unit having an evaporator, a condenser and means for circulating a heat exchanging refrigerant medium through the evaporator and condenser, a cover or hood for surrounding at least part of a freshly printed web of sheet material, a second container housing the evaporator, means for passing air and entrained volatile printing ink solvent vapour from the cover or hood through an input conduit to the second container, means whereby condensed solvent can be removed from the second container, a first container housing the condenser, a connecting conduit connecting the first and second containers through which connecting conduit air with or without entrained vapour can be passed from the second container to the first container to be heated therein, and a return conduit whereby the heated air with or without entrained vapour can be passed back into the cover or hood to evaporate and entrain more printing ink solvent.

For a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:—

Figure 1 is a diagrammatic view of apparatus of a first embodiment for carrying out the method of the invention,

Figure 2 is a diagrammatic view of apparatus of a second embodiment for carrying out the method of the invention,

Figure 3 is a diagrammatic view of apparatus of a third embodiment for carrying out the method of the invention as applied to a printing press, and

Figure 4 is a diagrammatic view of a fourth embodiment of the method of the invention as applied to a printing press.

In the accompanying drawings, arrows indicate the directions of flow or rotation of various components and materials and like parts bear like reference numerals.

In general terms the method of the invention for evaporating and condensing a volatile component is one in which a volatile component is evaporated to a vapour from a solid, a solution or a liquid mixture by waste heat of a condenser of a refrigerator unit applied di-

rectly to heat the solid, solution or liquid mixture and/or applied to heat a gas to be passed over or through the solid, solution or liquid mixture, and in which at least a substantial proportion of the evaporated volatile component vapour is then condensed to a liquid by an evaporator of the refrigerator unit.

Such a method can be applied to any process involving drying and/or distillation and enables the recovery of a volatile component or components used in the process, e.g. solvents, together with the utilisation of what would otherwise have been waste, heat. As shown in Fig. 1 a first embodiment for carrying out the method of the invention includes a refrigerator unit having an evaporator 1, a condenser 2 and means for circulating a heat exchanging refrigerant medium, in conventional manner, through circuit including the evaporator 1 and condenser 2. Conveniently the refrigerant medium, such as that known under the trade name Freon (Registered Trade Mark), is circulated by a compressor 3 through a discharge valve 4, through the condenser 2 where it gives out heat, from thence through a receiver tank 5, an expansion valve or flow control 6, the evaporator 1 where it takes in heat, and back into the compressor 3 *via* a suction valve 7.

The condenser 2 is housed in a first sealable container 8 which is connected *via* a connection conduit to a second sealable container 10 which houses the evaporator 1. Preferably the whole apparatus is thermatically insulated by means not shown, as is the case with the other embodiments illustrated in Figs. 2 to 4. In this embodiment the solid, solution or liquid mixture containing a volatile component to be removed therefrom is placed in the container 8 *via* an openable sealable aperture therein, where the heat given out by the refrigerator unit condenser 2 evaporates the volatile component. The volatile component vapour passes from the container 8 *via* the connecting conduit 9 into the container 10 in which it condenses to liquid on the evaporator 1 which extracts heat from the vapour and transfers it to the circulating refrigerant medium. The condensed volatile component is removed from the container 10 as necessary by means, not shown, such as a drain tap in the container base. The heated refrigerant medium is recirculated by the compressor pump to the condenser 2 where it gives up its heat to the solid, solution or liquid mixture in the container 8 to evaporate th volatile c mpon nt.

For example, to vapourise 1 gallon of ethanol from a soluti n or liquid mixture thereof and condens it again would requir a refrigerator unit of approximat ly 0.3 ton capacity. For such a unit using a refrigerant medium known under the trade name R12, and operating at a condenser temperature f 100°F (37.8°C) and an evaporator temperature of 20°F (−6.7°C) the coefficient of performance (heat absorbed from evaporator/heat energy equivalent of the energy supplied to the compressor) is of the order of 5.

Some volatile components with a high boiling point and/or low liquifaction temperature may be difficult to recover in the embodiment of Fig. 1. To facilitate recovery of such volatile components the embodiment of Fig. 1 may be modified by the insertion of a flameproof centrifugal pump or motor, such as shown at 11 in Fig. 2, in the connecting conduit 9. This pump functions to decrease the pressure in the container 8, and hence lower the boiling point of the volatile component when therein, and to increase the pressure in the container 10 and hence raise the liquifaction point of the volatile component vapour when therein. Alternatively or additionally a flameproof thermostatically controlled heater, not shown, may be located within the container 8 to augment the heat supplied by the condenser 2.

To enable several volatile components to be separated out at once the embodiment of Fig. 1 can be modified as shown in the embodiment of Fig. 2 in which the container 10 has inner walls or baffles 12 arranged to define therein a serpentine path for the vapour when therein. In this way the baffles 12 delineate successive compartments 13, 14, 15 within the container 10, arranged along the evaporator 1 in the direction of flow of refrigerant medium therein, to provide a graduated temperature drop for the vapour in the container 10, so that different volatile components may separate out in different compartments 13, 14, 15 in the container 10. The refrigerant medium is led into the evaporator 1 at an upper part 16 of the container 10 and led out of the evaporator 1 at a lower part 17 of the container 10 remote from the part 13 so that the compartments 13, 14, 15 effectively operate at different temperatures with the compartment 13 having the lowest temperature. Means for removing condensed volatile components from each compartment are provided, such as openable vents 18*a*, 18*b* and 18*c*. Liquid having highest boiling points will condense in compartment 15 and lowest boiling point liquids in compartment 13.

In all the embodiments of the invention a safety valve 19 as shown in Fig. 2 may be provided in the container 10 for venting excess pressure therein to atmosphere. Similarly the apparatus of all embodiments of the invention may be provided with means for discharging static electricity ther from to earth and may be mad of corrosion resistant materials such as stainless steel.

One of the main applications of the m thod of the invention is to a printing press for the recovery of printing ink solvent. In printing processes such as in gravure or flexographic

printing, a solvent rich printing ink, containing for example 80% solvent such as ethanol, ethyl-acetate, or toluene, is printed on to a web of sheet pap r by an engraving dispos d about a drum, and the printed paper is dried on a rotating perforated drum or about a set of rollers disposed, for example, in a circular array, by a stream of hot air. The vapours arising from the solvent mix with the air to form an exhaust gas, which can contain a considerable quantity of heat and solvent vapour, normally allowed to go to waste in the atmosphere causing pollution thereof.

As shown in the embodiment of Fig. 3 a web of sheet paper 20 is fed over a gravure printing drum 21 of conventional form, equipped with ink supply 22 and ink wiper blade 23. The web of sheet paper 20 is fed to and printed by the drum 21, and passed therefrom to a, preferably perforated, drying drum 24 disposed within a cover formed as an enclosure 25. Alternatively the drying drum 24 can be replaced by an array of rollers (not shown) arranged in circular array. Hot air from a return conduit 26 is in use fed to the freshly printed web of sheet paper 20 about the drum 24 to dry the ink whereupon the dried web leaves the enclosure 25 at 27. This enclosure is so designed that the web passes into and out of the enclosure through apertures such as 27 which minimise ingress to the enclosure of unheated air from the outside atmosphere.

The ink from the supply 22 contains substantial quantities of solvent and a solvent rich vapour forms, in use, within the enclosure 25 in the form of hot air and vapour of the volatile solvent evaporated by the hot air. An input conduit 28 leads the air and entrained solvent vapour out of the enclosure 25, preferably *via* a flameproof centrifugal pump or motor such as 29 in the conduit 28, to the refrigerator unit evaporator 1 (not shown) housed in the container 10. In the evaporator heat is taken from the air and entrained solvent vapour by the refrigerant medium introduced *via* the valve 6 and leaving after being heated, *via* the compressor 3. Solvent condensed from the air and entrained vapour in the container 10 is removed therefrom, conveniently *via* a line 30.

Cooled air, wholly or partially freed from entrained solvent vapour, leaves the evaporator container 10 *via* the connecting conduit 9 and optional flameproof centrifugal pump or motor 11 and enters the containers 8 housing the refrigerator unit condenser 2 (not shown). In the container 8 the air, with or without any entrained vapour, is heat d by the refrigerating medium passing through th condenser from the connecting conduit 9. After heating the air in the container 8, the refrigerating medium, now cooled, pass s back to the evaporator 1 *via* the valve 6 and the heated air leaves the container 8 through the return conduit 26, via an optional flameproof centrifugal pump 31 and an auxiliary thermostatically controlled heater 32, and is recycled back into the enclosure 25 to evaporate and entrain further ink solvent.

By the use of such apparatus, it is clear that expensive solvent losses can be mitigated and atmospheric pollution correspondingly reduced. Some heat and air can also be effectively recycled, reducing energy consumption and also reducing pollution due to residual solvent levels in the exhaust from the container 10.

It will be clear to the competent reader that modifications and variations can be imported without departing from the invention. Thus not all the air need be recycled: an auxiliary air intake can be provided at any convenient point. The number, dimensions and positions of the air and refrigerant medium circulation pumps can be altered at will, as can the auxiliary heater or heaters, to provide the temperature control and heat throughput desired. The overall dimensions and capacity of the apparatus can be varied to suit the scale of the printing operations with which it is to be used.

The embodiment of Fig. 4 is basically similar to that of Fig. 3 and like parts will not be described in detail.

The main features of difference in this embodiment are the form of cover or hood for the freshly printed web of sheet material 20 and the provision of means for effecting a transfer of heat between the heated air and entrained vapour leaving the cover or hood and the cooled air returning to the cover or hood. The hood 25*a* is shaped to define a path, substantially V-shaped in plan, through which the web 20 passes. The input conduit 28 is connected to the apex of the V-shaped hood *via* the flameproof centrifugal pump or motor 29 and the return conduit 26 has two branches 26*a* each connected to one of the arms of the hood near the extremities thereof *via* individual pumps 31. Each return conduit branch 26*a* is provided with an individual thermostatically controlled heater 32, and the extremities of the hood arms are shaped to conform closely to the web dimensions to afford limited access of air into the hood from the outside atmosphere.

The means for effecting transfer of heat between the heated air and entrained vapour leaving the hood 25*a* and the cooled air returning to the hood, takes the form of a heat exchanger element 33 housed in a third container 34, with the element 33 providing part of the flow passage of th input conduit 28 between the hood 25*a* and evaporator container 10, and with the container 34 providing part of the flow passage of the return conduit 26 b tween th condenser container 8 and the hood 25a. To this end the contain r 34 has an inlet 34*a* for the return

conduit 26 and two outlets 34*b* for the two branches 26*a*. In this way some heat is extracted from the heated air and entrained vapour leaving the hood 25*a* before it enters the evaporator container 10 where the vapour condenses and is removed *via* an outlet vent 35.

To minimise the presence of water vapour in the air circulating in the apparatus of Figs. 3 and 4, the input conduit or the element 33 can include a housing for containing a dehydrating agent such as silica gel or activated alumina. Similar provision for a dehydrating agent may be made for the embodiments of Figs. 1 and 2. In all embodiments at least the containers, the or each conduit and the cover or hood when present preferably are thermally insulated with, for example, fibreglass, polyurethane or isocyanurate foam. Additionally, to minimise corrosion, the parts of the apparatus subject to corrosive attack may be made of or coated with corrosion resistant material such as stainless steel. All apparatus preferably is provided with means to discharge static electricity therefrom.

CLAIMS

1. A method of evaporating and condensing a volatile component, in which a volatile component is evaporated to a vapour from a solid, a solution or a liquid mixture by waste heat of a condenser of a refrigerator unit applied directly to heat the solid, solution or liquid mixture and/or applied to heat a gas to be passed over or through the solid, solution or liquid mixture, and in which at least a substantial proportion of the evaporated volatile component vapour is then condensed to a liquid by an evaporator of the refrigerator unit.

2. A method according to claim 1, in which the solid, solution or liquid mixture or the gas to be passed over or through the solid, solution or liquid mixture is received in a first sealable container housing the condenser, which first container is in communication with a second sealable container, housing the evaporator, *via* a flameproof centrifugal pump or motor, and in which the pressure in the first container is decreased and the pressure in the second container is incrased above atmospheric pressure by pump or motor to lower the boiling point of the volatile component in the first container and to raise the liquifying point of the volatile component vapour in the second container.

3. A method according to claim 2, in which the volatile component in the first container is heat d additionally by a flam proof thermostatically controlled heater.

4. A method according to claim 2 or claim 3 as applied to a printing press for recovering printing ink solvent, in which heat d air is passed over a freshly printed web of sheet material to vapourise voltaile printing ink solvent and entrain it therein, the air and entrained solvent vapour are passed to the second container wherein a substantial proportion of the solvent vapour is condensed to liquid solvent by the refrigerator unit evaporator and removed therefrom, and the partially cooled air and remaining entrained solvent is passed from the second container to the first container where it is heated by the refrigerator unit condenser, and returned to the printed web of sheet material for further solvent evaporation.

5. A method according to claim 4, in which the air and entrained solvent vapour leaving the printed web are passed to the second container through a heat exchanger element over which is passed the heated air returning from the first container to the printed web, so that heat is given, at the element, from the air and entrained solvent vapour leaving the printed web to the heated air returning to the printed web.

6. A method according to claim 4 or 5, in which the printed web is lead through a cover or hood, wherein the heated air is passed over the web, in a manner such as to minimise ingress of unheated air from the outside atmosphere.

7. A method according to any one of claims 4 to 6, in which the air and entrained solvent vapour leaving the printed web are passed through or over a dehydrating agent to remove water vapour from the air.

8. A method according to any one of claims 4 to 7, in which parts through and over which the air with or without entrained solvent vapour is passed are earthed to dissipate static electricity.

9. A method according to any one of claims 2 to 8, in which the volatile component vapour is led through the second container in a serpentine path so as to provide a graduated temperature drop for the vapour in the second container and thereby condense separately different boiling point volatile components from the vapour.

10. Apparatus for carrying out the method of claim 1, including a refrigerator unit having an evaporator, a condenser and means for circulating a heat exchanging refrigerant medium through the evaporator and condenser, a first sealable container for receiving the solid, solution or liquid mixture from which a volatile component is to be evaporated or for receiving a gas to be passed over or through the solid, solution or liquid mixture, which first container houses the condenser, and a second sealable container, in communication *via* a c nnecting conduit, with the first container, for receiving volatile component vapour to be cond nsed and housing the evaporator.

11. Apparatus for carrying out the method of claim 4, including a refrigerator unit having an evaporator, a condenser and means for circulating a heat exchanging refrigerant medi-

um through the evaporator and condenser, a cover or hood for surrounding at least part of a freshly printed web of sheet material, a second container housing the evaporator, means for passing air and entrained volatile printing ink solvent vapour from the cover or hood through an input conduit to the second container, means whereby condensed solvent can be removed from the second container, a first container housing the condenser, a connecting conduit connecting the first and second containers through which connecting conduit air with or without entrained vapour can be passed from the second container to the first container to be heated therein, and a return conduit whereby the heated air with or without entrained vapour can be passed back into the cover or hood to evaporate and entrain more printing ink solvent.

12. Apparatus according to claim 11, including a heat exchanger element housed in a third container, the element providing part of the input conduit flow passage and the third container providing part of the return conduit flow passage.

13. Apparatus according to claim 11 or claim 12, wherein the means for passing air and entrained volatile printing ink solvent vapour from the cover or hood through the input conduit to the second container, includes a flameproof input centrifugal pump or motor connected to the input conduit.

14. Apparatus according to any one of claims 11 to 13, including at least one flameproof return centrifugal pump or motor providing part of the return conduit flow passage.

15. Apparatus according to any one of claims 11 to 14, in which the cover or hood is an enclosure containing a drying drum or array of rollers over which drum or rollers a freshly printed web of sheet material can be passed, the enclosure being provided with inlet and outlet means for the web affording limited access of air to the enclosure from the outside atmosphere.

16. Apparatus according to any one of claims 11 to 14, in which the cover or hood defines a path, substantially V-shaped in plan, through which a freshly printed web of sheet material can be passed, the input conduit being connected to the apex of the V-shaped path, the return conduit being connected to both arms of the V-shaped path near the extremities thereof, and the path being shaped to afford limited access of air to the enclosure from the outside atmosph re.

17. Apparatus acc rding to any one of claims 11 to 16, including a housing f r a dehydrating agent in the input c nduit.

18. Apparatus according to any one of claims 11 to 17, including at l ast one auxiliary th rmostatically controlled heater connected to the return conduit.

19. Apparatus according to any one of claims 10 to 18, in which at least the containers, the or each conduit and cover or hood when present, are thermally insulated.

20. Apparatus according to any one of claims 10 to 19, including a flameproof centrifugal pump or motor in the connecting conduit between the first and second containers.

21. Apparatus according to any one of claims 10 to 20, including a flameproof thermostatically controlled heater located within the first container.

22. Apparatus according to any one of claims 10 to 21, including a safety valve in the second container for venting excess pressure therein to atmosphere.

23. Apparatus according to any one of claims 10 to 22, including means for discharging static electricity therefrom to earth.

24. Apparatus according to any one of claims 10 to 23, in which the second container has inner walls arranged to define therein a serpentine path arranged to provide a graduated temperature drop for vapour whilst in the second container.

25. A method of evaporating and condensing a volatile component, substantially as hereinbefore described with reference to any one of Figs. 1 to 4 of the accompanying drawings.

26. Apparatus for carrying out the method of claim 1, substantially as hereinbefore described with reference to Fig. 1 or Fig. 2 of the accompanying drawings.

27. Apparatus for carrying out the method of claim 4, substantially as hereinbefore described with reference to Fig. 3 or Fig. 4 of the accompanying drawings.

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